

ET Docket No. 03-137 - Comments on the Proposed Changes in the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields

Comments on Near-Field EME Calculations

***Summary:** This submission summarizes some of the technical aspects near-field EME calculations and highlights that there is some confusion in the terminology that can be traced to the use of a “electric field near-field” and a “magnetic-field near-field”. It is further suggested that the FCC consider incorporating a separate calculation for H-field, which is a 360-degree effect (even for panel antennas).*

Along with other potential changes in OET-65 we believe that calculations dealing with “near-field” emissions are deserving of close scrutiny. In past years the primary installation configuration for Cell and PCS providers has been “tower” sites, which require near-field work only for occupational situations (not generally a factor in permitting situations with localities). More recently “rooftops” are becoming the site of choice thus near-field calculations are becoming more prevalent so that RF exposure situations can be more fully defined for general public safety concerns.

With regard to the behavior of RF, all calculations are basically attempts to mathematically model and describe that behavior. But remember, Nature does what Nature does, the math doesn't take precedence over it, i.e. Nature leads.... the math follows.

In attempts to model near-field activity several existing formula are taken from OET-65. One in particular, equation #12, page 27:

$$R_{nf} := \frac{D^2}{4 \cdot \lambda}$$

Another version of this from White, is:

$$R_{nf} := \frac{2 D^2}{\lambda}$$

In both cases the “D” tries to relate to “antenna aperture”, which *should* always be a fraction of the working wavelength.

However, here it is suggested as the length or width of the overall antenna structure. When applied this way to typical panel antennas (using FCC eq 12), the results suggest that near field extends to about 6 ft at cellular frequencies and about 12 ft at PCS frequencies (using White's aperture calculation the values for cellular and PCS are 44 ft and 100 ft respectively). In other words, near-field is inversely proportional to wavelength. This is backwards to reality.

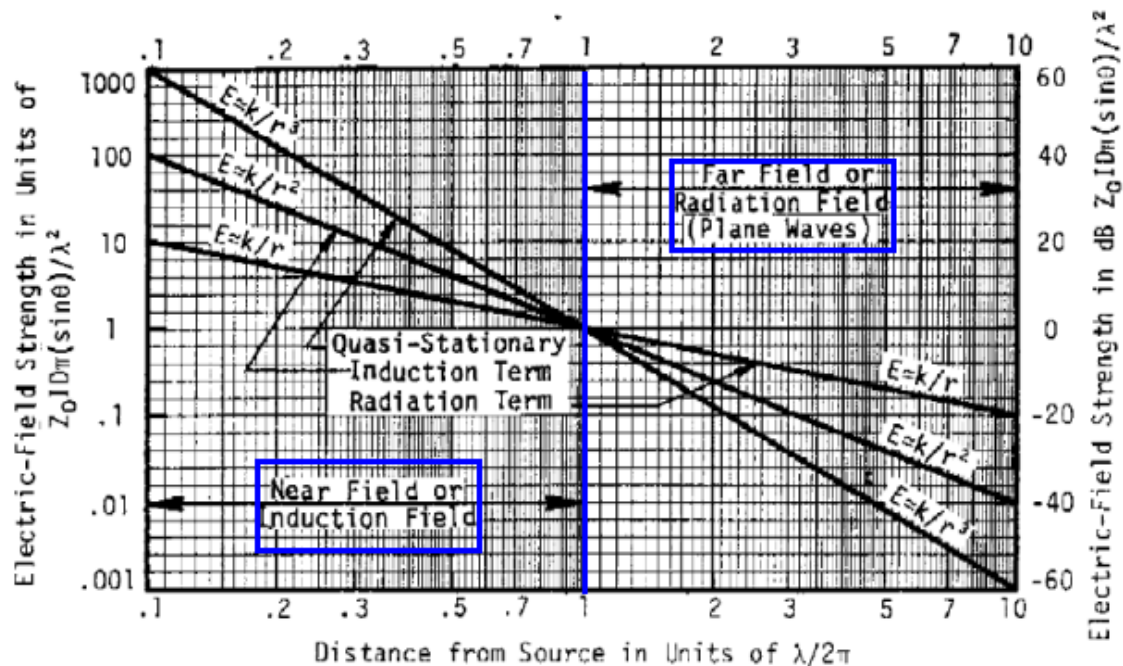
The real problem arises from the definition of antenna aperture and the way it equates to "D" and must be calculated. From that lack of clarity there has likely been some mis-assessment of roof top sites.

Antenna aperture is not a specification found on any manufacturers spec sheets. Further, most manufacturers can't even supply that data when asked. It is a theoretical moment of point source. A value this elusive, therefore, should not be the pivotal requirement for these calculations.

The more generic form of the equation to define the magnetic near-field boundary is:

$$R_{nf} := \frac{\lambda}{2\pi}$$

See below, as defined by D. White some years ago:¹



¹ White, Don, EMI Control Methods and Techniques: Volumes 1 through 5, Don White Consultants, Gainesville, VA.

This equation doesn't require mysterious, elusive or misleading values and follows the generally accepted theory that the near-field limit is proportional to wavelength.

One model used by one of the authors of this paper over the last two decades, and one which generally agrees with measured results, requires calculating or measuring E and H wave independently, the two results are summed, and a %MPE is calculated.

This makes sense because in the near-field area, the E and H fields do not have the usual "normal" relationship relative to each other, and therefore can constructively add to the exposure environment. It is prudent to accept the worst-case situation where they create constructive interference patterns and behave additively, and follow this practice.

E-Field

Within the transition zone (i.e. near-field), two things are occurring. The E-wave component is increasing in voltage to accommodate the new working impedance (377 ohms) while spreading in spatial distribution; a function of distance. Remember this is a generally loss-less process, so $KVA=KVA$. Therefore to maintain the same power from a 50-ohm system to 377 ohms of free-space the output voltage must transition "up". The two activities counter the effects of each other and thus can be stated as:

$$\frac{ERP}{4 \pi r^2}$$

ERP: The power radiated in the direction of interest. For E-field this will be the source power times the antenna gain in the specific direction of concern. E-field conforms to the antenna plot architecture.

r: The distance from the radiating body in meters.

The result will be in **Watts / m²**. Multiplying by 1000, yields **mW / m²** and dividing the result by 10000 will yield an answer in **mW / cm²**, the generally accepted form by the FCC.

H-Field

H-wave is a function of the current being delivered from the initial 50-ohm system. Its highest moment is as it leaves that antenna and is strictly related to the “source power current”; it does not conform to the antenna plot pattern at that moment. (Here’s where antenna aperture might be useful, but not essential.)

Here, as well, two things are happening. The current is decreasing to conform to the new working impedance (377 ohms) and decreasing as a function of spatial distribution. In this case the two work together and can be expressed as:

$$\frac{SP}{4 \pi r^3}$$

SP: is the source power being fed to the antenna in watts

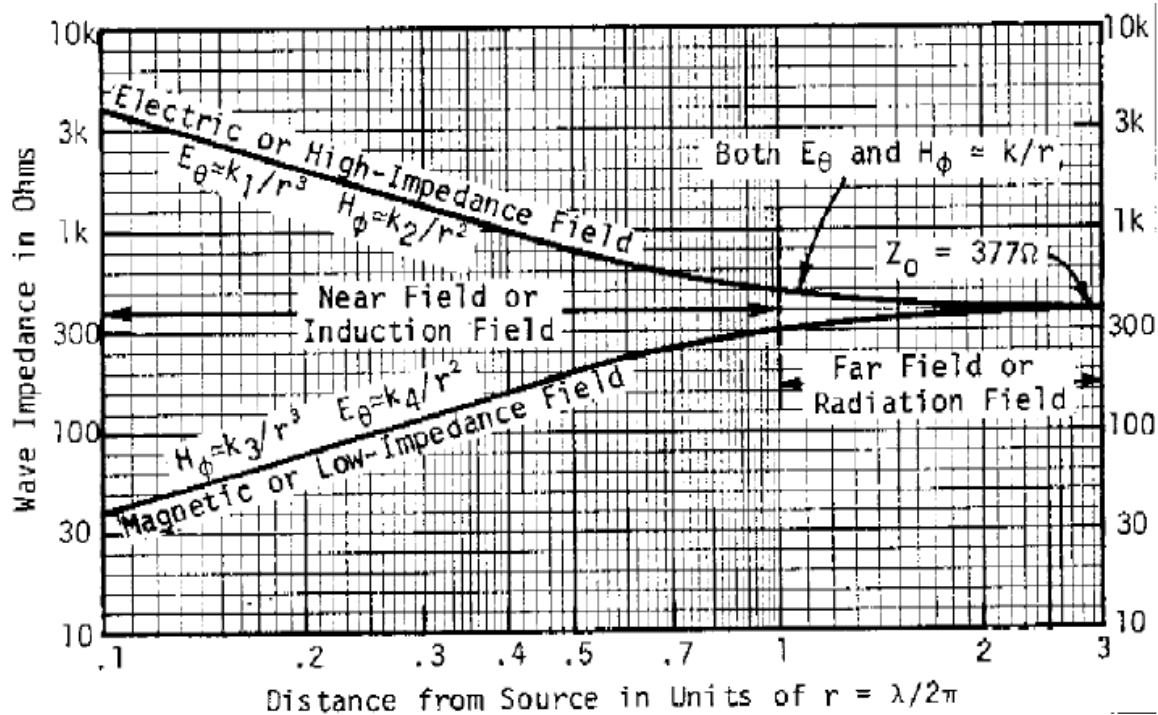
r: is the distance from the radiating body in meters.

Here again the result will initially be in **Watts / m²**. Multiplying by 1000, yields **mW / m²** and dividing the result by 10000 will yield an answer in **mW / cm²**.

Unlike E-field, H-field is not attenuated by the metal backplane of a panel antenna. The H-field will emanate over 360 degrees. It is the result of this attribute that has lead to descriptions referring to cylindrical models and spherical models to describe the near-field environment. In fact, there are only a limited number of materials that can shield from H-field. This attribute accounts for why H-field is the predominant plane wave selected for DF (direction finding) applications. It reflects less frequently and therefore an H-field receiver site suffers less from multi-path, again a DF issue.

Extent of the Near Field zone

In the strictest sense, it can be seen on following graph, from White that the absolute limit of the NF transition zone is $3 \lambda / 2 \pi$.



However the authors of this paper, along with a large portion of industry, use the 10 rule (i.e. 10λ). At the extent of 10 wavelengths the statistical probability of constructive interference patterns resulting from reflection and re-radiation from bodies in close proximity creating peak moments of EME in excess of MPE no longer exist.

A mathematical derivation, based on equivalent aperture that generally supports the 10λ Figure is included in a separate comment submittal.

Note: This does not include the ground reflectivity coefficient, which accounts for uniform field reflection and is indiscriminate of phase. The extent of 10λ may be considered excessive and could be a point of debate, however, this weights the calculation series conservatively in favor of public safety.

Beyond “Magnetic” Near Field

Outside of near-field or “far-field” both E and H waves decay at the rate of $ERP / 4 \pi r^2$ or $SP / 4 \pi r^2$. In practice, however, only the E-field need be dealt with. At or beyond 10λ the H-field component will not constructively add to the E-field, so only the E-field needs to be considered.

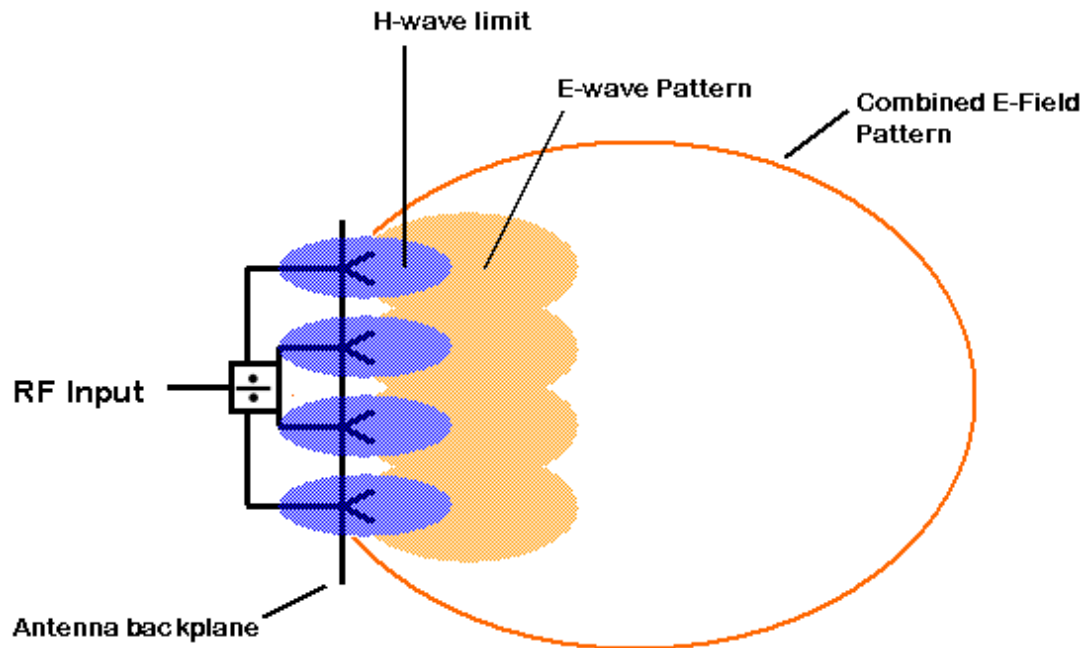
There is one final point of confusion that requires some clarification. There appears to be two different definitions referred to as “near-field”.

The first definition, referred to here as the “magnetic” near-field, and generally more widely accepted quantity by antenna engineers, is that of the activity of “H-wave” as described in the above paragraphs as a field that emanates in all directions, unimpeded in the “magnetic” near-field.

The second definition, the “electric” near-field, is the distance from multi-element collinear array at which the fields from the multiple elements converge and can begin to be treated as a single point source, or “plane wave”.

The FCC’s current definition of near-field as described in OET-65 is this “electric” near-field definition but is not the same as the “magnetic” near-field limit.

The “plane-wave” boundary can easily prove to be much greater distances from the antenna than the “H-field” from the old school. This value is useful in modeling the final lobe shape of a radiator, but has little to do with the limits of the “H-field” transition zone, as in the following diagram:



Suggested modifications to OET-65

The FCC has published effective guidance on algorithms to model near-field and far-field exposure situations, and how to apply them. Currently, under the most conservative and prudent FCC guidance, the RF environment is modeled as the lesser of the near-field, as modeled by the cylindrical equation 20 in OET-65, and the far-field model (equation 6 in OET-65). This appears to be a technically reasonable and tractable procedure for modeling the RF environment in most situations

There is one situation where this method appears to break down, and that is for areas close to a modeled emitter. In the case of a panel antenna, it has previously been stated that H-field effects exist even on the back of the panel. We feel that it is prudent to add H-field specific calculations so that these previously unaccounted for effects can be modeled, and potential hazards identified.

We suggest that the commission may wish to consider that for areas closer than 10λ , the H-field model be applied as described in previous paragraphs to be:

$$\frac{SP}{4 \pi r^3}$$

The H-field can be applied as an additive quantity to the cylindrical model to provide a prudent, conservative figure. As stated, the H-field would be appropriately applied over a 360-degree radius, even for panel/sectorized antennas.

With the prevalence of rooftop antenna sites, and the general public and occupational hazards that are potentially created, in addition to the potential occupational hazards on tower sites that are receiving renewed attention by the commission and other agencies, it would seem that it is an appropriate time to attempt to include real effects of H-field in the modeling analysis of wireless installations.

Respectfully,

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